The line derived from specimen *ED* is of special interest, since within it appeared the greatest diversities that were found during the entire investigation. The progeny of *ED* had a mean spine number of 9.91 and a mean diameter of 23.51 units (fig. 1, *E*). At the same time the mean spine number of the parent line (*E*) was 10.99 and the mean diameter was 27.05 units, giving a difference in mean spine number of 1.08 and in mean diameter of 3.54 units. Furthermore the differences persisted for many generations and until the line was discontinued. Specimen *ED* therefore fulfilled the conditions usually required of a mutation, i.e., it was a sudden large variation that was inherited.

From line *ED* there were derived three branches, *EDA*, *EDB* and *EDC*, that quickly exceeded in diameter and spine number any other branches in the entire family 58. The largest specimen appeared in branches *EDB*. It had 20 spines and a diameter of 40 units (fig. 1, *F*). These branches, however, soon died out for some unknown reason, although they were cultivated as carefully as possible.

The general conclusion reached is that within a large family of *Arcella dentata* produced by vegetative reproduction from a single specimen, there are many heritably diverse branches. These diversities are due both to very slight variations and to sudden large variations ('mutations'). The formation of such hereditarily diverse branches appears to be a true case of evolution that has been observed in the laboratory and that occurs in a similar way in nature.

[1] Middleton, A. R. J. Exp. Zool., **19**, 1915. (451–503.)
[2] Jennings, H. S. Genetics, **1**, 1916, (407–534.)

THE IMPORTANCE OF NIVATION AS AN EROSIVE FACTOR, AND OF SOIL FLOW AS A TRANSPORTING AGENCY, IN NORTHERN GREENLAND

By W. Elmer Ekblaw

Crocker Land Expedition, American Museum of Natural History, and University of Illinois

Communicated by J. M. Clarke, July 12, 1918

Nivation and solifluction, two closely related and important physiographic processes of Arctic lands, are perhaps nowhere better illustrated than in those coastal areas of northern Greenland not covered by the permanent ice-cap. The climate and the topography are favorable to the high development of these processes; the rather heavy snowfall that melts gradually during the short summer promotes the work of nivation; and the high relief, with numerous small plateaus and generally steep slopes, affords opportunity for the action of solifluction. The presence of an 'ice-table' everywhere, not deep below the surface, is an added favorable condition. As a consequence

nivation and solifluction attain a degree of importance in northern Greenland not generally appreciated.

Nivation is the process by which quiescent neve effects the disintegration of rocks, and the destruction of some land forms, and the formation of others. In this process the snow itself produces very little, if any, effect; it is the water from the gradual melting of the snow that does the work. The melting must be so slow and gradual that the water does not escape by surface run-off, but soaks into the layer of rock fragments or soil above the ice-table, and then seeps slowly downward and outward from its source.

Nivation is assuredly most effective in regions of pronounced relief, and strong and variable winds, conditions prevalent in Greenland. Under such conditions, the snow does not lie as a mantle of uniform thickness, but is piled up in drifts of various kinds. For the sake of clearness, I have classified these drifts into two, or three, rather distinct divisions, more or less characteristic of the kinds of localities in which they are found. These divisions are (1) *dome-shaped drifts*, formed on the more or less uneven tops of plateaus, on the small plain areas, and on other relatively level surfaces; (2) *piedmont drifts*, formed along the foot of extended cliffs, or series of cliffs; and (3) *wedge drifts*, formed in gullies and small gorges near the top of cliffs.

The *dome-shaped* drifts vary in size with the size of the plateau or plain surface upon which they lie, and with the strength and character of the winds that blow over. On the small segments of a plateau surface dissected by gullies or stream beds, these dome-shaped drifts may not be very large or very thick; on larger segments, they may form one large dome, or several, all, or some, very thick,—in cases even becoming small ice-caps. Thus there may be every gradation from small dome-shaped drift to the great ice-cap of Greenland. If the winds that blow over vary considerably and rather uniformly in direction, the domes are somewhat symmetrical; if not, they slope gradually toward the windward side, and quite abruptly on the other. On the plateaus north of Foulke Fjord, the winds blow from almost all points of the compass, as often, almost, from one direction as another, and the drift slopes almost uniformly from the center to the whole peripheral edge; on Herbert Island, where the winds blow generally from the South, the dome slopes gently in that direction, while on the north side, the slope is abruptly precipitous. Very few of the tops of the plateaus are free from dome-shaped drifts; and many terraced moraines, deltas, and plains are covered by the same form.

The *piedmont* drifts are those that form along the cliffs on the windward sides of valleys, fjords, and straits, on the lee sides of capes, peninsulas, and islands. They are formed from the snow that comes drifting over the lands back of the cliffs, and piles up on the talus slopes below, at the foot of the cliffs. Thus, both sides of Foulke Fjord are bordered for almost nine months of the year by these piedmont drifts, those on the north side from the snow carried over by northerly winds, those on the south from the snow carried

over by southerly winds. In Inglefield Gulf, only the south side is thus bordered because the cliffs on that side are more continuous, and the winds carry the snow from the plateaus over in great quantities; whereas on the north side, more broken by rather large valleys, the winds are deflected down the valleys, and little, if any, snow is carried over. Similar differences occur in other fjords.

The *wedge* drifts which form in gullies and small gorges near the top of the cliffs are genetically related to the piedmont cliffs, and consequently are distributed in much the same manner. They, however, are included within limited areas, and though in places they may be considered continuous with, and part of, the piedmont drifts, in other places they are the only drifts formed, for all the snow is carried into the gorges and gullies by the winds which are deflected into them The character of the drifts is so closely a function of the topography, the direction of the wind, and the consistency of the show, that as any one of these factors changes in character, the drifts may also change In Grenville Bay, for instance, the south side is bordered by piedmont and wedge drifts, while the north side is almost bare of snow; and since the south side gradually changes its direction from northeast-southwest at its mouth, to a nearly due east-west direction toward its head, and the prevailing wind is a general south-by-westerly, a regular succession develops, from tiny wedge drifts near the mouth, to a full-fledged glacier at the head, a glacier heading in a cirque a mile from the coast.

As long a quiescent neve covers the ground, and protects it from changes in temperature and from weathering, little disintegration or degradation can take place. It is only when the snow melts that the work begins. The melting in North Greenland is not a rapid process. Even when the sun shines at its highest, the temperature of the air does not rise much above 55° F.; it is usually lower, though that of exposed soil and rocks may be considerably higher. The snow drifts melt rather slowly, fastest at their edges.

Each of the kinds of drifts described produces different effects when melting. The dome-shaped drifts on the level surfaces melt first at their peripheral edges. The water formed is very near 32° F., and freezes at every drop of temperature due to cloudiness or change of wind so that excessive frost action takes place at the margin and just beyond, with consequent breaking up and disintegration of the rock. Often, too, the water freezes on the side of the drift away from the low sun, even at noondays, thus increasing the freezing action. Just beyond the margin of the drift, the temperature of the water is a little higher, and solifluction sets in. The disintegration of the rock, and the movement of resulting material, progresses in toward the center of the snow-drift covered area, as the drift melts back. Horizontal solifluction and consequent altiplanation terraces so clearly defined by H. M. Eakin,[1] are the immediate effect, and these in time result in reducing the plaeau top, or other plain surface, to a quite level surface, constantly being extended in area, and lowered. The process has been so well described by

Mr. Eakin that I merely call attention to this phase dependent upon the melting of the dome-shaped drifts.

The piedmont drifts formed on the lee slopes, or at the foot of the lee cliffs, act somewhat differently. The melting edges are at the top of the drift, and at the bottom. At the top the process is a sapping one, cutting back the cliff; at the bottom solifluction is the dominant process, though generally there is also some direct transportation by excess surface water that does not seep through the soil. The drift melts down from the top, and back from the foot. F. E. Mathes,[2] in his discussion of the glacial sculpture of the Bighorn Mountains, illustrates a cross section of such a drift, and the direction of the erosive attack upon the cliff. From the lower edge of the cliff where solifluction begins, the movement of the soil may continue to the foot of the slope, in one continuous sheet, or it may progress in a series of steplike slopes, or sloping terraces, with crescentic terminal margins, like festoons. Throughout northern Greenland these piedmont drifts are numerous, and almost invariably they give rise to similar solifluction slopes. When they occur on both sides of a V-shaped valley they tend to grade the sides and build up the bottom until it becomes U-shaped, as Mathes has described.

The wedge drifts formed in gullies and small gorges near the tops of cliffs, while acting in the same way as the piedmont drifts, produce different results. When these wedge drifts melt, the sapping process mentioned in the piedmont drifts cuts back the sides and the head of the gully or gorge in such a way as gradually to give it the form of a segment of a circle, the depth and extent of the segment depending upon the amount of snow blown into it. In this way a typical cirque may be initiated. When the snowdrifts become so large that they do not melt during the summer, ice gradually forms and a glacier occupies the floor of the cirque; frequently, though, the snow all melts away during the summer and no ice is formed, yet the cirque-form continues and the process goes on. A cirque in which ice has played no part can usually be distinguished by its rough and uneven floor, not at all like the scoured floor of a cirque once containing a glacier. The *bergshrund* in these high latitudes does not play an important part in cirque formationas it apparently does farther south, even in those cirques in which glaciers are formed; in the cirques carved by nivation alone there is, of course, no bergshrund at all.

Nivation is unquestionably of prime importance in the development of some of the topographic forms of the Greenland coast, and plays no small part in the degradation of the high cliffs, and the grading of the slopes.

Solifluction as defined by J. G. Andersson[3] is the process by which masses of the regolith saturated with water (which may come from melting snow or rain), flow slowly from higher to lower ground. This saturated, semi-fluid substance, not at all assorted as to size of fragments, moves along in much the same way as a glacier. H. M. Eakin[1] defined the process of solifluction as the migration of detritus under the thrust and heave of frost action. He

recognized and described several types of soil movement and resultant topographic forms.

In northwest Greenland, solifluction is closely connected with nivation. For it is under conditions best suited to nivation that soil flow is best developed as a transporting agency. If precipitation be in the form of rain, most of the water flows away as surface runoff and its chief work is then the characteristic ordinary stream action. But if precipitation be in the form of snow—as it is in northern Greenland—which melts rather slowly and gradually, little of the water flows away on the surface. Most of it seeps into the ground, saturates it, and forms a more or less pasty mass according to the relative proportions of soil and water. The presence of an ice-table, in that it effectually prevents the seepage of water below the depth of the ice, facilitates soil flow. Thus, perhaps, the principal conditions necessary to solifluction are snowfall, with gradual melting of the snow, and an ice-table to prevent, or at least retard, the seepage of water deep into the ground.

Several forms of solifluction occur in Greenland, including probably all that have been observed elsewhere. Distinction should be made between solifluction which causes progressive motion of surface material such as results in altiplanation terraces, solifluction slopes, and soil streams or soil glaciers; and that which causes only circulatory movement such as may result in 'polygon-boden.' It is the first of these forms of solifluction which is one of the most important important transporting agencies in northern Greenland, and which has produced there land forms similar to those described by Eakin in Alaska, and by Andersson and others elsewhere. The other of these forms is also generally prevalent in Greenland, but while it is an active agent of movement contributory to the breaking up and degradation of the detritus, it is not so important as a transporting agent.

Throughout northern Greenland, every land area free of ice and snow during the short summer, exhibits the solifluction slopes and altiplanation terraces described by Eakin from Alaska. Both on the slopes and on the plateaus, the terraces resulting from solifluction are every where conspicuous. In northwestern Greenland, particularly, solifluction of these types is a most important transporting agency; the removal of detritus resulting from nivation, freezing and insolation, to the few torrential streams that bear it onward to the sea, is quite dependent upon solifluction. In many valleys the streams at the bottom of the valleys are not nearly large enough to remove the detritus brought down by solifluction, and the valley fast fills up, with lakes in the depressions, behind the dams of more abundant, or faster moving, detritus. On the gentler slopes, the rate of movement is not high, but on some of the steeper slopes the movement is rapid.

Though the type of solifluction resulting in solifluction slopes and altiplantation terraces is the dominant and most important type in northern Greenland, other types are very well represented. From this important type to rock slide on the one hand, and to circulatory movement that re-

sults in 'polygon-boden' on the other, every gradation of type of soil-flow may be found, and the combined results of their activities is a transportation of material as important as that of the streams and glaciers.

All the field evidence tends to show that nivation and solifluction, characteristic processes of disintegration and denudation under subarctic or arctic conditions, are of prime importance in the reduction of the high relief of northern Greenland.

[1] Eakin, H. M., *Washington, U. S. Geol. Survey, Bull.* 631, p. 76, 1916.
[2] Mathes, F. E., *Washington, U. S. Geol. Survey, 21st Ann. Rep.*, p. 181, 1899–1900.
[3] Andersson, J. G., *Chicago, J. Geol., Univ. Chicago*, **14**, 1906, p. 91.

ON THE α-HOLOMORPHISMS OF A GROUP

By G. A. Miller

Department of Mathematics, University of Illinois

Communicated by E. H. Moore, July 18, 1918

The term α-holomorphism was introduced by J. W. Young to denote a simple isomorphism of a group G with itself which is characterized by the fact that each operator of G corresponds to its α^{th} power.[1] A necessary and sufficient condition that an abelian group of order g admits an α-holomorphism is that α is prime to g, and J. W. Young proved in the article to which we referred that when a non-abelian group admits an α-holomorphism the $(\alpha-1)^{th}$ power of each of its operators is invariant under the group and the group admits also an $(\alpha - 1)$-isomorphism. Moreover, these conditions are sufficient for the existence of an α-holomorphism.

The object of the present note is to furnish a complete answer to the following question: For what values of α is it possible to construct non-abelian groups which admit separately an α-holomorphism? It will be proved that no such group is possible when α is either 2 or 3, but that for every other positive integral value of α there is an infinite system of non-abelian groups each of which admits an α--holomorphism.

The fact that every group which admits a 2-holomorphism is abelian results directly from a theorem noted in the first paragraph of this article. If a non-abelian group G admits a 3-holomorphism we may represent two of its non-commutative operators by s_1, s_2, and note that as a result of this holomorphism the two dependent equations

$$s_1^3 s_2^3 = (s_1 s_2)^3, \qquad s_1^2 s_2^2 = (s_2 s_1)^2$$

must be satisfied. Since s_1^2 and s_2^2 are invariant under G it results directly from the latter equation that $s_1 s_2 = s_2 s_1$, and hence the assumption that s_1 and s_2 are non-commutative led to a contradiction. That is, *if a group admits a 3-holomorphism it must be abelian.*